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# PROCEEDINGS

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## DISCUSSION OF MISSISSIPPI RIVER VALLEY GEOLOGY RELATION TO RIVER REGIME

(*Published in July, 1951*)

By Leo M. Odom, Stafford C. Happ, and Harold N. Fisk

WATERWAYS DIVISION

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# DISCUSSION

LEO M. ODOM,[6] M. ASCE.—The geological report on the alluvial valley of the Mississippi River, prepared by the author for the Mississippi River Commission, that is outlined briefly in this paper, is a true milestone in the work of collecting and analyzing information concerning the great river and its valley. This collection and analysis has been in progress since the earliest settlements were located along its banks.

During past years students have arrived at various conclusions regarding the geology of the valley. Sir Charles Lyell in 1845, for instance, deduced that the valley plan of the Mississippi has been subjected to great oscillation of level varying from 100 ft below its present level to its former position. Each theory has been more or less discounted or has been proved to be insufficient in scope by subsequently available data.

The author's investigation was made at a time when it appears that practically everything necessary for a study had finally been secured. The geology of the continent is now well understood. Thousands of borings, many of them of great depth, had been made and logged; but of probably the greatest value, a great portion of the valley had been mapped by aerial photography, furnishing a new tool for the study of land forms more accurate and much more detailed than had ever been available before.

The need for a new comprehensive geological study in the light of the wealth of information accumulated since the last effort was one of the prime problems that faced Max C. Tyler, M. ASCE, when he became president of the Mississippi River Commission. The cutoff program having been largely completed, stabilization of the river was the next big problem. An over-all picture of the characteristics of bed and banks could only be obtained by such a study. General Tyler was fortunate to obtain the services of a man with the competence and vision of the author for this study. The geological investigation carried on concurrently with a laboratory investigation of the meandering of alluvial rivers and various researches on type and effects of revetments, dikes, dredging, and other factors have provided a greatly expanded volume of dependable information for the guidance of engineers engaged in river work.

The geological background of the river with which it is necessary to deal today, as developed by the author, would have been beyond the scope of the training and imagination of most engineers. The fact that it offers a reasonable and productive concept of the formation of the valley must be gratefully accepted. The portion of the paper devoted to the mechanics of meandering and alluviation is, however, within the field of every day experience and treats of phenomena that have been the subject of engineering investigations since the earliest days of work on the control of rivers.

It is granted that the generalized statements concerning scour, fill, and meandering are probably sufficient for the purposes and scope of the paper.

NOTE.—This paper by Harold N. Fisk was published in July, 1951, as *Proceedings-Separate No. 80*. The numbering of footnotes is a continuation of the consecutive numbering used in the original paper.

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For engineering usage, however, no such positive rules can be accepted. For example, there are many locations on the river at which the deepest holes and maximum caving are far removed from the concave bank. At Point Menoir (Mile 253 above Head of Passes) and Free Nigger Point (Mile 234 above Head of Passes) there are deep scour holes caused by eddies very near the convex bank. In the bights of these bends depths near the concave bank are relatively small. These bends come under the class of those mentioned by the author in the section on "Control of River Behavior by Alluvium" as occurring where the river impinges against the valley wall. However he does not mention the locations of the scour holes. At many other locations the greatest depth in bends is near the center of the river. Off Algiers Point, for instance, where there is no impingment against valley walls, the greatest depths are near the convex bank and are in excess of 200 ft below mean sea level.

In studying the processes that mould and modify the river today, the geologist's field laps with that of the engineer. It is to be hoped that a cooperative study of the processes will be carried on until definite answers are obtained.

The author's use of the obscure term "point of bend" brings to mind the paucity and unsatisfactory character of the terminology used in river engineering. The writer has often found it very difficult in preparing reports to reserve the terms "point" and "crossing," for instance, for the phenomena for which they are the only accepted names. Geologists are noted for the invention of names, so much so that their vocabulary has become a study in itself. The writer for one would be grateful if they would evolve definitive words to denominate river phenomena.

STAFFORD C. HAPP[7].—The importance of the studies, ably and conveniently summarized in this paper, is not limited to the lower Mississippi engineering problems, important as those are, but without doubt will have much wider influence in both the engineering and geological fields. The recent geological investigations of the Mississippi alluvial valley have provided a major advance in the knowledge of river behavior, and related geomorphic principles. The complex alluvial deposits and river processes have not previously been so concisely and clearly described. This paper will be especially useful in bringing to wider attention the studies that have been previously described in more detail, but in media of limited circulation. It is still to be hoped that more of the original, basic field data will be published for critical study in the geological profession.

The author interprets the geological history essentially in terms of river entrenchment following late Pleistocene lowering of sea level by glacial ice accumulation, and subsequent aggradation due to post-glacial rise of sea level. These basic concepts will probably not be seriously questioned, but some further details of his interpretation of the alluviation are less convincing, and alternate hypotheses deserve more consideration than they are accorded in print. The questionable details include:

[7] Geologist, Corps of Engineers, U. S. Army, Kansas City, Mo.

(1) Postulate of a braided-channel river to account for accumulation of the substratum of some 100 ft to 300 ft of clean sands and gravels;

(2) A gradual change in the nature of deposition to produce an "original topstratum" of finer-textured sediment;

(3) Beginning of the present meandering habit on the lower slope near the mouth only after the sea had almost reached its present level, with meandering developing upstream as aggradation progressed and the slope was lowered; and

(4) Adjustment of the river to "its constant base level," and thereby attaining a "poised" condition in which it is neither aggrading nor degrading, but only reworking its older alluvial deposits within meander belts of several successive courses in various parts of the alluvial valley.

It is not necessary to postulate a braided channel phase in order to account for the sand and gravel substratum, or a change in deposition to account for the topstratum. There is no reason why a meandering river cannot aggrade its bed and flood plain, and accumulate a considerable substratum of sand and gravel beneath a silt and clay topstratum. Sand and gravel are usually bed load materials and are sorted and left behind in point-bar ridges, or lateral accretion deposits, as a meandering channel shifts within its flood plain. In time the bed load deposits are covered by finer materials deposited from shallower overflow waters, usually slowed by vegetation, and thus a topstratum is formed over sands and gravels of only slightly greater age. From a geological viewpoint, flood plain topstratum and substratum are formed concurrently and are of the same age. If more bed load reaches the river than it can carry away, the lateral accretion deposits will gradually be built to higher elevations, and thus a thickening substratum will accumulate and be covered by the topstratum which is being eroded away on the outer sides and replaced on the inner sides of channel bends. The relatively thick sandy substratum, and finer topstratum, thus could have been produced by the same river processes which Mr. Fisk has described as operative in the present Mississippi valley, without requiring any changes in base level, or in river behavior.

The only direct evidence for former braided channels appears to be the surface pattern of terraces in the upper part of the valley. These are quite different from the pattern of the meander belts, and the terraces are reported to slope beneath the flood plain in a downstream direction; but the surface features may reflect only a late, minor phase in terrace development, or possibly even slight surface erosion. The Rio Grande is an aggrading river above Elephant Butte Reservoir in central New Mexico, and has a braided channel, but during the prolonged major flood of 1941 most of its flow was concentrated in a relatively narrow, deepened, winding course within the wider sands of the usual braided channel. Aggradation is comparatively rapid on the Rio Grande, relative to meandering, and considerable parts of the topstratum are covered with bed load sands by river avulsions during floods; yet meander patterns are prominent on the flood-plain surface. Where aggradation is relatively less rapid than meandering, the sand substratum will be thickened while the topstratum is repeatedly reworked and replaced at higher elevations, rather than being buried. It seems probable that meandering would have been predomi-

nant on the lower Mississippi, which generally has not aggraded its bed more than about 100 ft since the late Pleistocene entrenchment.

The postulate that meandering began on the flatter slope near the mouth, and gradually developed upstream, also seems questionable. The relatively straight and stable present course below Donaldsonville, is ascribed to resistance to meandering by the thick clay topstratum. This implies relatively straight original courses on relatively flat slopes, which is in accord with conditions observable on the new deltas of artificial lakes. If the present river does not meander on its flatter slopes, however, it appears illogical to postulate that the ancestral river first developed meandering on the flatter slope near its mouth. It seems that meandering would be more likely to develop farther upstream, where steeper slope and less resistant sandy banks would be more conducive to lateral bank cutting and channel migration. Individual meanders certainly shift in a downstream direction, and this would facilitate downstream, but not upstream, extension of a meandering pattern.

It is suggested, as an alternate hypothesis apparently in accord with the geological evidence, that the lower Mississippi was probably a meandering river throughout much, if not all, its period of aggradation, and that its past deposits and future history are most reliably interpreted in terms of its present observable processes of behavior. This implies that meandering has been sufficiently active to remove and replace topstratum deposits before they would otherwise be buried by aggradation, except in the flatter delta where aggradation presumably has been largely a thickening of the topstratum. This hypothesis does not require a former braided channel condition, nor any "change in deposition" to account for an "original topstratum." The present thicker flood-basin or backswamp deposits are accepted as those parts of the flood plain which, by chance, have remained longest outside the meander belts. The lower elevation of the sands under such areas may be evidence of progressive aggradation. Finally, and most important, this hypothesis implies that the present river is the product of a long period of aggradation, rather than being the product of a new and more stable "poised" regime.

The concept of the "poised" river is useful, and the terminology is apt. It is important, however, to understand that it is based on lack of recognizable aggradation or degradation during the comparatively short period of accurate measurements. Levee building, revetment to protect eroding banks, dredging of crossings and shoals, removal of snags and clearing of banks, artificial river cutoffs, partial flood control by reservoirs, and changes in surface runoff and increased soil erosion due to clearing of forests and agricultural practices, all have affected river behavior to some extent, but in varying ways, within the period of records. It is doubtful whether geologic trends can yet be determined from data affected by so many factors. The Mississippi delta will continue to grow into the Gulf of Mexico, however, and further aggradation of the river is a logical result to be expected; but the rate and extent of such aggradation, and the effects of other factors, are uncertain. The poised condition may be sufficiently well verified to indicate that neither aggradation nor degradation is rapid enough to affect engineering plans within periods of a few decades, or so; but it would appear unwise, from present data, to conclude that aggradation will not require consideration within the near future.

HAROLD N. FISK[8].—The remarks of Mr. Odom concerning the value of the writer's geological investigation of the alluvial valley of the Lower Mississippi River are greatly appreciated. It is the writer's belief that no generalization based on either geological or engineering studies of over-all river activity can be formulated as a hard and fast rule for interpreting a local engineering problem. Although cooperative work between geologists and engineers is highly desirable for a complete understanding of river phenomena, the answer to any local question must rest on the accumulation of sufficient data necessary for proper analysis. Field evidence has fully supported the writer's generalizations that deep scour pools occur within bendways in areas where the river impinges against the valley walls, or in other areas, such as those near New Orleans, which Mr. Odom mentions, where realtively impermeable bed and bank materials strongly resist bank caving. It has long been known that the position of a scour hole varies slightly from time to time in a bendway and that its position varies with each bend. In order to explain satisfactorily the location of an individual scour hole in a bendway, it is necessary to obtain detailed data concerning such factors as changes in river alinement associated with stage variation and with bend migration, and the local character of bed and bank materials.

In directing attention to the lack of satisfactory terminology for Mississippi River phenomena Mr. Odom has touched on a subject which plagues both engineers and geologists. There is a great need for definitive and descriptive terms since many of those in use today originated with early boatmen. Although such terms may have sufficed for the needs of men navigating the river, they are certainly inadequate for detailed expression required in the technical description of river activity.

In his thought-provoking discussion, Mr. Happ expresses disagreement with the writer's views that during the epoch of valley alluviation the Mississippi River has changed from a braided to a meandering stream. He suggests that the Mississippi River probably has maintained its meandering habit during the time the valley was being aggraded. All of the data on which the writer's concept of the Mississippi River activity has been based are summarized in the paper under discussion, and those pertinent to questions raised by Mr. Happ will be restated here.

Perhaps the most convincing proof that the Mississippi River was a braided stream until late in the history of valley development can be obtained from the aerial photographs. These disclose many old braided channel scars on the surface of the large low alluvial fans which slope away from the mouths of each tributary valley. The fact that fans are in places buried by modern flood-plain deposits indicates they were constructed in large part while valley slopes were somewhat steeper than at present. Like similar features in other areas, extension of the foot of each of these fans was accompanied by entrenchment of headward areas. As a result the upstream part of each fan surface now rises as a low terrace above the flood plain while, downstream, the slope of the surface carries it below flood-plain level. Braided stream scars that converge toward the mouth of the upper Mississippi valley can be traced down-

[8] Chf., Geologic Research, Humble Oil and Refining Co., Houston 1, Tex.

stream into areas where the alluvial fan and flood-plain surfaces merge. In some areas individual braided channels can be seen to change gradually into meanders. Braided courses have also been mapped for other major tributaries, such as the Arkansas, White, and the Ohio Rivers, demonstrating that the change from braided to meandering habit was not limited to the Mississippi River, but was brought about by regional changes affecting river activity.

An outstanding feature of the Mississippi valley alluvium is the absence of silts and clays in those parts of the substratum away from the Mississippi River meander belts or below depths of river scour in those belts. Samples in these areas from thousands of borings which have completely penetrated the substratum show only "clean" sands or gravels. The matrix of the substratum is composed of sand grains which decrease in size upward in the section and down valley. As interpreted by the writer, these changes in grain size record a gradual loss in stream carrying capacity resulting from a progressive decrease in slope during valley aggradation. They also show that at any given time of alluviation the valley slope was lower in the river mouth areas than upstream. The matrix sands enclose thin lenticular bodies of pebbles, cobbles, and boulders of very local extent. Particles comprising these masses also decrease in size seaward; pea-sized grains are the coarsest recorded in the substratum near the modern shoreline. Lentils are distributed throughout the substratum and are found characteristically developed in areas where the "clean" sands extend close to the surface of the alluvial fans. In such areas, the shape, thickness, and distribution of the lentils can be closely correlated with the width, depth, and other characteristics of the shallow braided stream courses. Borings show that the sand accretions of the meandering Mississippi are large thick bodies in comparison with the lenticular masses in the substratum. The point bar deposits within the meander belt accretions typically incorporate thick swale fillings of fine sands, silts and clays. In addition, these deposits include extensive fine-grained fillings for cut-off meander channels. Insofar as no such fine-grained deposits are found in the substream below or away from the meander belts, it is difficult to relate the buried "clean" sands to meandering stream action. These relationships form a firm basis for assuming that the Mississippi River was a braided stream throughout much of the history of valley aggradation. They do not support the hypothesis proposed by Mr. Happ that the substratum represents bed load of sands and gravels which were sorted and left behind in point bar ridges or accretion deposits as the meandering Mississippi shifted with its floodplain.

In concluding his discussion, Mr. Happ expresses doubt that the poised condition of the Mississippi River has existed long enough to establish a geologic trend. He apparently believes that the only available critical evidence that the river is neither aggrading nor degrading its channel is confined to observational data obtained by engineers during the period of historical records. It is true that in presenting the concept of a poised stream, Gerard H. Matthes, Hon. M. ASCE, used engineering data and observation of river activity over the past 150 years. However, one of the principal conclusions reached by the writer as a result of his alluvial valley studies was that the Mississippi River has been maintaining its poised character since the sea

reached its present level. Since that time the river has constructed and abandoned its meander belt along the ancient Bayou Teche and Lafourche courses and has developed its present channel below Donaldsonville. Careful comparison of the lengths of the ancient courses, their natural levee heights, and the widths and depths of their channels, with similar features of the modern Mississippi River, demonstrates that the poised condition has existed for at least 2,000 years.

The writer appreciates this opportunity to clarify and strengthen interpretations presented in the paper. He feels that the wealth of data, the extensive borings, the comprehensive photographic coverage, and the detailed mapping of the Mississippi valley so amply substantiate the conclusion drawn as to preclude the necessity for appealing to alternate hypotheses as suggested by Mr. Happ.

*Acknowledgment.*—The illustrations used in the paper were taken, directly or slightly modified, from the figures and plates originally presented in publications of the Mississippi River Commission and Waterways Experiment Station.[2,3,4]

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